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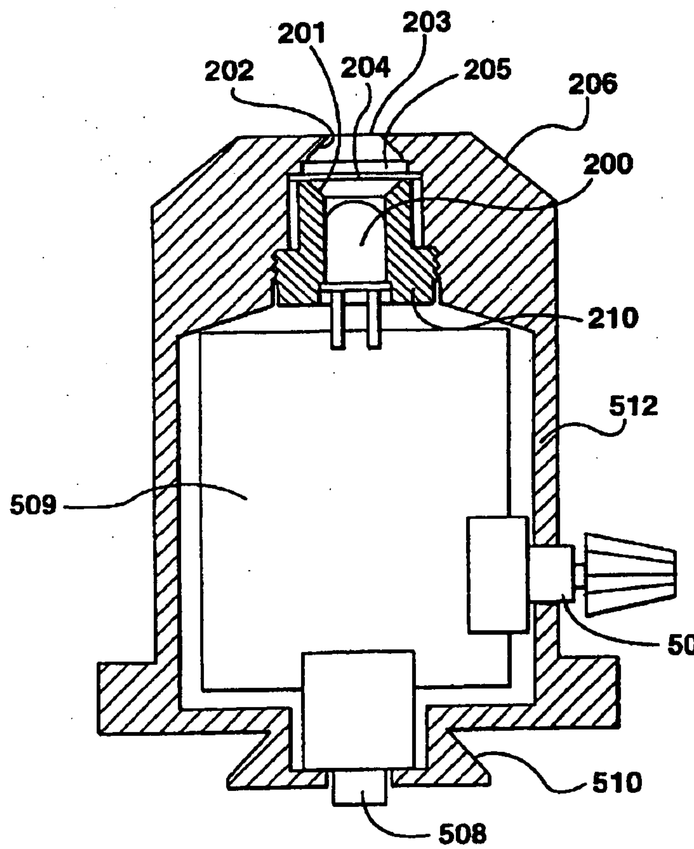
(54) Titre : METHODE ET SYSTEME D'ECLAIREMENT D'UN MICROSCOPE
(54) Title: METHOD AND SYSTEM OF MICROSCOPE ILLUMINATION



(57) Abrégé/Abstract:
A novel illuminator for a field microscope, which takes the place of the condenser and the light source and collimating optics in a traditional microscope, is described. The illuminator is described in several embodiments which cover bright-field transmitted light, bright-field reflected light, dark-field transmitted light and dark-field reflected light as well as uni-directional oblique and slit-

(57) Abrégé(suite)/Abstract(continued):
ultra illumination techniques. The light sources are modular so that they can be interchanged on the microscope, and they feature ultra-low power and current consumption, integral dimming control, battery power and light weight. Optically the illuminators offer extremely flat field illumination along with excellent colour correction or selectable narrow wavelengths. The illuminators are characterized by high optical efficiency and small size.

ABSTRACT

A novel illuminator for a field microscope, which takes the place of the condenser and the light source and collimating optics in a traditional microscope, is described. The illuminator is described in several embodiments which cover bright-field transmitted light, bright-field reflected light, dark-field transmitted light and dark-field reflected light as well as uni-directional oblique and slit-ultra illumination techniques. The light sources are modular so that they can be interchanged on the microscope, and they feature ultra-low power and current consumption, integral dimming control, battery power and light weight. Optically the illuminators offer extremely flat field illumination along with excellent colour correction or selectable narrow wavelengths. The illuminators are characterized by high optical efficiency and small size.

METHOD AND SYSTEM FOR MICROSCOPE ILLUMINATION

FIELD OF THE INVENTION

The Present invention relates to improvements to illuminator means for field, internal computer and bench microscopes.

DEFINITIONS

For the purpose of this patent application the following definitions apply throughout:

LED: LED is used to mean light emitting diode which may be either single colour such as red, green, blue, yellow, infrared or ultraviolet LEDS in any case type.

Laser diode: Any of the wide variety of semiconductor laser light emitting diodes including infrared, visible and ultraviolet laser diodes.

Diffuser: Any light diffusing material such as opal glass, sandblasted optical material, etched optical material, milky plastic or holographic diffuser material, but most particularly the family of white Teflon™ materials and a proprietary material called Spectralon™ made by LABSPHERE.

BACKGROUND OF THE INVENTION

Past patents proposed many ways of constructing microscopes and designing illumination systems for microscopes. One series of embodiments of the illumination system described in this patent is particularly suitable for field microscope use since in it employs a white LED as the light source. This offers a very high efficiency daylight like light source

which is ideal for field use in that it is small, light, low power and can be easily supplied by battery or solar cell energy sources. It is different from other LED microscope light sources such as the one described in US patent 5,489,771 in that it uses a different and far more efficient approach to achieve flat field illumination and high efficiency in a daylight like source along with wavelength shaping, dimming control and battery power.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a novel method and system for producing LED based illuminators for compound microscopes which feature modular interchangeability, small size, low weight, high efficiency, low cost and ease of construction.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will now be described, by way of example only, with respect to the attached Figures, wherein:

Figure 1 shows a first embodiment of an illuminator in accordance with the present invention,

Figure 2 shows similar type of illuminator to Fig. 1 except an optical component is used to isolate the external environment from the diffuser surface, and to further shape the illuminating cone leaving the illuminator;

Figure 3 shows a similar type of illuminator to Fig. 1 except a plurality of LEDs is used to increase the light output level from the illuminator and a solid optic is used to isolate the external environment from the diffuser surface,

Figure 4 shows an illuminator where six LEDs are arranged in such a way as to provide selectable colour content in the output from the illuminator,

Figure 5 shows a darkfield illuminator employing reflective optics and LEDs,

Figure 6 shows a simpler version of the darkfield illuminator,

Figure 7 shows a fibre optic or light guide version of the illuminator,

Figure 8 shows a novel field microscope employing one embodiment of the illuminator.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is concerned with the design of high efficiency illuminators which employ LEDS, laser diodes and specifically white light LEDs with internal phosphor conversion methods. Several versions of such illuminators are described which cover the application areas of field microscopy and condenser replacement illuminators for new or retrofit use on conventional style upright and inverted microscopes.

PREFERRED EMBODIMENTS

In Figure 1 is shown a simple single LED microscope illuminator for a field microscope in which the LED 200 supplies light to a diffuser 205 through a limiting filter

204. In this case the filter 204 limits the UV light component from the LED 200 from leaving the illuminator so there is no UV content from the illuminator. The filter in this case is a Lee theatrical filter, part number 226, UV blocking filter and the LED is a white light LED which uses a 470nm blue LED with a phosphor coating to convert a substantial part of the emitted light from the UV and blue portion of the spectrum to a daylight like broad spectrum light. In other cases the filter can be, for instance, a UV transmitting and visible light absorbing filter used with a 470nm blue LED to act as a UV illuminator for fluorescence microscopy with transmitted light. The T-1 3/4 style LED shown is chosen since it produces a well defined 15 degree beam of light.

The light from the LED 200 strikes the diffuser 205 with a diameter to fill the clear aperture of the rear side of the diffuser. A portion of the light passes through the diffuser and a portion s reflected from the back surface. The portion reflected from the back surface of the diffuser strikes the rear reflective optic surface 201 and is reflected back at the diffuser to increase the efficiency of the illuminator due to back side losses from the diffuser. The light passing through the diffuser either directly exits the outlet of the illuminator via port 203 which in this case is an open port with no window, or strikes the front reflective optic surface 202 and is reflected back to the diffuser front surface. The size of the opening of the illuminator port, the angle of the front reflective optic and the diameter of the clear aperture of the front surface of the diffuser all act to set the numerical aperture of the illuminator. The numerical aperture can be set to match the highest expected aperture of the objectives used with this illuminator. The illuminated field diameter is set by the diameter of the port

opening in the front surface of the illuminator. This port size may be adjusted by means of an iris diaphragm or by a series of sliding or rotating fixed apertures. The rear reflective optic 202 is machined into the surface of the LED mounting component 210 and may be as machined aluminium or may incorporate broadband or narrow band reflective coatings on its surface. The front reflective optic is machined into the internal surface of illuminator body 512 and may be as machined or may incorporate broadband or narrow band reflective coatings on its surface. Where it is desired to protect the diffuser from dirt or fluids a window can be incorporated to seal the port opening 203 from the external environment. Such a window limits the effective numerical aperture due to total internal reflection. Illuminators of this type without windows have been tested and have achieved numerical apertures greater than 0.80 NA.

The LED is powered by external power via connector 508 or internal battery power (not shown) which is controlled by intensity adjustment control 507 which sets the current and voltage supplied to the LED by control circuit located on printed circuit board 509.

The LED 200 can be any type of LED or laser diode. The diffuser can be Teflon™, spectralon™ or any similar diffusing material which diffuses substantially all of the angles and wavelength of light impinging on it, including glass, ground glass, opal glass or etched glass. The diffuser can be incorporated internally or externally wavelength converting materials which can shift the wavelength of the LED or laser diode wither to shorter or longer wavelengths as desired. The wavelength converting materials include phosphors, frequency conversion crystals and other similar materials.

In other patents such as US Patent 5,489,771 another type of LED illuminator is described except it uses chip type LEDS which are direct coupled to a diffuser block. The designs described herein use discrete LEDS and reflective optics with a diffuser to accomplish a higher efficiency and a controlled numerical aperture of illumination. They also employ white light LEDs and utilize electronic control of the LED intensity and low power regulation circuits.

In Figure 2 a plano convex lense 260 is used to form an isolation between the external environment and the diffuser surface. The lense 260 is cemented into the outlet opening of the illuminator to form a fluid and gas tight seal. The optical characteristics of the lense limit the angles of light which can leave the diffuser/reflector area since many trajectories of light experience total internal reflection at the air glass interface of the lense. This limits the maximum NA from the illuminator and produces a more defined beam with less stray light than the version shown in Fig. 1.

In Figure 3 two LEDs 270 and 280 are shown with their beams directed to diffuser 203. If two identical LEDs are employed then the brightness of the illuminator can be increased while if two different wavelength LEDs are employed then the illuminator can supply tailored spectral output to match a particular application need.

A different type of outlet window design is also shown in this figure. The output port is occupied by an optical component 281 which incorporates the front reflective optical components into its outer surface 288 as a reflective mirrored surface with either broadband or narrow spectral reflectance characteristics. This optical component 281 has a plane front

surface which forms the coupling surface of the illuminator so that the illuminator can be oil coupled to a slide to allow high numerical apertures to be achieved. The rear side of the optical component 281 also has a plane surface to that it can be cemented, oil or fluid coupled or otherwise optical coupled or contacted to the diffuser 203 front surface. In this type of illuminator there may be more than one control means 283 to individually control the separate LEDs. Alternatively the LEDs can be controlled via signals from the connector 282 in order to coordinate the illuminating system with the observing system of the microscope.

Figure 4 shows a similar type of illuminator in which six LEDs 401 through 406 (402 through 405 not shown but arranged in a circular array about the vertical centre axis of the illuminator) are used to illuminate the diffuser 203. Here the rear reflective optic has its primary mirror surface at 408 and secondary surfaces at 410 and 411. In such an illuminator the control the individual LEDs would typically by external control signals via connector 409 but it could also be by six internal controls 412 arranged around the base of the illuminator.

In Figure 5 is shown a darkfield condenser replacement using an LED illumination system. The particular type of darkfield condenser shown here is a cardioid design but this type of illuminator can be used with virtually any type of darkfield condenser design including those with patch stops where the cone internal reflector can form the patch stop. The LED 500 send a beam of light upwards toward the primary mirror 501, which is a mirrored hollow in the circular glass part 502, which then directs the light towards the secondary mirror 503. The secondary mirror 503 is a mirrored outside surface of circular glass part 504. The top surface of glass part 504 forms the outlet window for the light from

the condenser and can be flat or a truncated inverted cone. This surface is flat on the top surface to allow oil coupling to the slide carrying the object to be viewed. The two glass parts 502 and 504 are cemented or bonded together so that light can pass the boundary between the two components at low angles of incidence without total internal reflection. Since a portion of the light from the LED normally strikes the middle of the primary mirror where it would reflect back to the LED instead of carrying on to the secondary mirror, a set of reflective optics 505 and 513 are used to configure the light path so that the light is preferentially sent to the portions of the primary mirror where it then passes to the secondary mirror. Since the light strikes the conical reflector surfaces at grazing angles it is important to note that the light is still substantially parallel, or within a small angular spread when it strikes the primary mirror. The conical reflector 511 can be mounted on a spider at the top of reflector 505 or alternately it can be adhered to the underside of glass part 502. The reflector 513 sets the outside diameter of the beam of light from the LED and is formed on the internal surface of part 505 so it also serves as the mounting means for the LED 500 which is adhered in the bore of the reflector 505. The reflector 511 sets the diameter of the hollow central region of the beam of light from the LED. In some cases the reflectors 513 and 511 may be used alone with suitable angles to form a dry type darkfield illuminator (not shown) with numerical apertures to suit the application and objectives chosen. The reflectors 513 and 511 increase the efficiency with which light from the LED is conveyed to the outlet window of glass part 504. In the version of such an illuminator as shown the LED 500 is supplied with controlled power from the electronic dimmer circuit which is contained on

printed circuit board 509. Power to this printed circuit board is supplied through power connector 508. The intensity of the light from the illuminator is controlled by potentiometer 507. The overall illuminator is contained in housing 512 which is approximately the same size as a traditional darkfield condenser. The housing 513 has a mounting flange or dovetail 510 made to mate with the microscope type it is intended for. Inside the housing 512 is a means for supporting the reflector 505 which is here shown as part 506.

Such darkfield condensers can be configured with single LEDs as shown or with multiple LEDs of same colour inside the reflector optics 513 and 511 to increase the brightness, or with multiple colour LEDs either in the form of discrete LEDs, LEDs containing multiple die or discrete LED chips, to control the wavelength content of the emerging light from the condenser.

The general idea of using an LED in a darkfield condenser has been previously proposed and successfully carried out by J. Dutton as described in Quekett Bulletin No. 33 December 1998 page 29. It is the intent of this patent to show improvements to the scheme he proposed to increase the efficiency, intensity, and control of intensity and wavelength of such an LED powered darkfield condenser.

Figure 6 shows a simplified version of Figure 5 with only the external rear reflective optic 513 on the internal surface of 505. This application can be particularly suited to laser diode applications where power levels are not difficult to achieve and efficiency is not such a consideration. It is also suitable for applications such as darkfield auto-fluorescence where

a powerful beam of blue or UV light is desired to initiate spontaneous fluorescence of a sample object.

Figure 7 shows a typical LED based illuminator where the diffuser is moved to the outer surface of the illuminator at 701. The diffuser may also be omitted and a plane polished first surface may be employed. The optical component 703 consists of a light guide formed by a suitable optical material which can be glass, plastic, GRIN material or fibre optic bundles. The material is contoured to be cemented to the LED at interface 705. The numerical aperture of the illuminator is set by the angles of the internal reflective surfaces 704 which may be omitted in applications where numerical aperture is not important. The LED is held in place by mounting block 702 which keeps the LED in contact optical part 703 if they are not cemented together.

Figure 8 shows a typical application of one style of these illuminators as a modular microscope stage, illuminator, and control system all in one integrated package.

The module includes a stage module100 which includes an LED 101 which may be a coloured LED or which may be a white light emitting LED which employs a system of several LED chips to achieve white light either internally to the LED encapsulation or as a set of discrete chips or die, or which may be a white light emitting LED where the white light is achieved by a phosphor coating on the LED die or on or in the LED plastic encapsulation so that the original substantial monochromatic light from the LED die is converted to broad spectral content white light. The LED emits light which strikes the diffuser 106 so that part of the light is transmitted by the diffuser 106 in the forward direction to the outlet of the

illuminator 127 and part of the light is reflected by the diffuser and strikes the reflector optic surface of part 102 which serves a dual function to hold the LED in place and to reflect light back to the diffuser surface. Of the light transmitted by the diffuser a portion directly leaves the outlet of the illuminator 127 while light which is not within the acceptance angle of the output reflector 126 is reflected back to the front diffuser surface 106. This pair of mirrors acting on the front and back sides of the diffuser greatly increases the efficiency of the illuminator.

The cone of light from the diffuser can be tailored to any desired numerical aperture to match the maximum numerical aperture of the objective lenses used with the field microscope by the selection of the angles of the reflector surfaces of reflector 126 and by the diameter of the diffuser 106 and the illuminator outlet opening 127. The surface of the front reflector 126 may be a plane surface or a curved surface. The distance from the diffuser 106 to the LED 101 is determined by the cone angle of the light emitted by the LED and the diameter of the diffuser. The edge of illuminated circle of the cone angle of the LED should match the clear aperture of the diameter of the diffuser. The angle of the rear reflector optic 102 should be chosen to maximize the return of reflected light to the diffuser and may be a plane surface or a curved surface.

A filter material 128 which may be an interference filter or a film or gel type filter may be used to remove unwanted light from the illuminator output. This is particularly true where the LED is a phosphor based white light emitting LED which uses a blue LED as the

exciting source for the phosphor and where the blue LED emits UV light as part of its overall spectral output. In this case a material such as LEE Filter number 226 UV blocking gel is selected to remove the UV light from the LED output. The LED is powered from a printed circuit board 103 which contains the regulating and dimming electronics to control the LED brightness 105 and a control potentiometer 104 which is used to manually adjust the brightness of the LED.

The light from the illuminator passes through the glass slide 107 to illuminate the object 108 with a cone of flat light of spectral content determined by the choice of LED 101.

TYPICAL ILLUSTRATIVE APPLICATIONS AREAS

The illuminators described herein are particularly useful in field and remote laboratory applications. Third world laboratories carrying out pathological bacterial or scientific research will benefit from the availability of such condensers which can be used with existing microscopes as a retrofit item.

Current scientific researchers in traditional major research labs can also benefit from the extremely uniform field of illumination made available by these condensers. Another area of application is in microscopy where wavelengths outside the visible spectral range can be detrimental to the sample object. The white LEDs employed herein do not emit light outside the normal spectral range and any minimal UV or IR content if present can be readily filtered with commercially available filtering components. The low photon levels and

virtually zero UV and IR content suggests these types of condensers for long term studies of cells especially in fertilization work for in vitro fertilization.

We Claim:

1. A microscope illuminator, comprising:

an LED illumination source;

a diffuser disposed to be illuminated by the LED illumination source, wherein the diffuser diffuses substantially all of the angles and wavelengths of light impinging thereon;

a rear reflector, wherein light diffusing backwards from the back surface of the diffuser either strikes the rear reflector or the LED illumination source, light from the rear reflector being reflected back to the diffuser where the light may transfer through the diffuser and leave the illuminator.

2. A microscope illuminator as in claim 1, wherein substantially all light traveling forward from the diffuser reaches the sample directly or strikes a front reflector, wherein the front deflector returns the stray light to the front surface of the diffuser or sends it to the sample.

3. A microscope illuminator as in claim 2, wherein the front and rear reflectors surround the diffuser and have planar surfaces.

4. A microscope illuminator as in claim 2, wherein the front and rear reflectors surround the diffuser and have spherical surfaces.

5. A microscope illuminator as in claim 2, wherein the front and rear reflectors surround the diffuser and have conical planar surfaces.

6. A microscope illuminator as in claim 2, wherein the front and rear reflectors surround the diffuser and have conical spherical surfaces.

7. A microscope illuminator as in any of claims 1 - 6, where the illumination source includes at least one LED, and a filter is placed in the light path between the LED and the sample.

8. A microscope illuminator as in claim 7, where the filter corrects the color temperature of the LED emission to a desired color temperature.

9. A microscope illuminator as in claim 7, where the filter is incorporated into the structure of the diffuser.

10. A microscope illuminator as in any of claims 2 - 6, wherein the illumination source is one or more white light emitting LEDs, where the white light is created by light from a blue LED striking a phosphor which then emits white light, and where such LEDs are located in a slide/sample holding base of the microscope.

11. A microscope illuminator as in any of claims 1 - 10, wherein the light from the diffuser is constrained by one or more reflective surfaces to a cone of suitable numerical aperture to illuminate an object.

12. A microscope illuminator as in any of claims 1 - 10, wherein a plano-convex or plano-plano lens is used to form an isolation between the external environment and the diffuser surface.

13. A microscope illuminator as in claim 12, wherein the lens is cemented into the outlet opening of the illuminator to form a fluid and gas tight seal.

14. A microscope illuminator as in any of claims 1 - 10, wherein an optical component having a planar front surface forms a coupling surface for the illuminator.

15. A microscope illuminator as in claim 14, wherein the optical component has a planar rear surface that is coupled to the front surface of the diffuser.

16. A microscope stage including a microscope illuminator according to any of claims 1 - 15, wherein the light from the diffuser reaches a specimen plane of the stage without passing through an intervening condenser or collimating lens.

17. A microscope including a microscope illuminator according to any of claims 1 – 15, wherein the light from the diffuser reaches the object being viewed without passing through an intervening condenser or collimating lens.

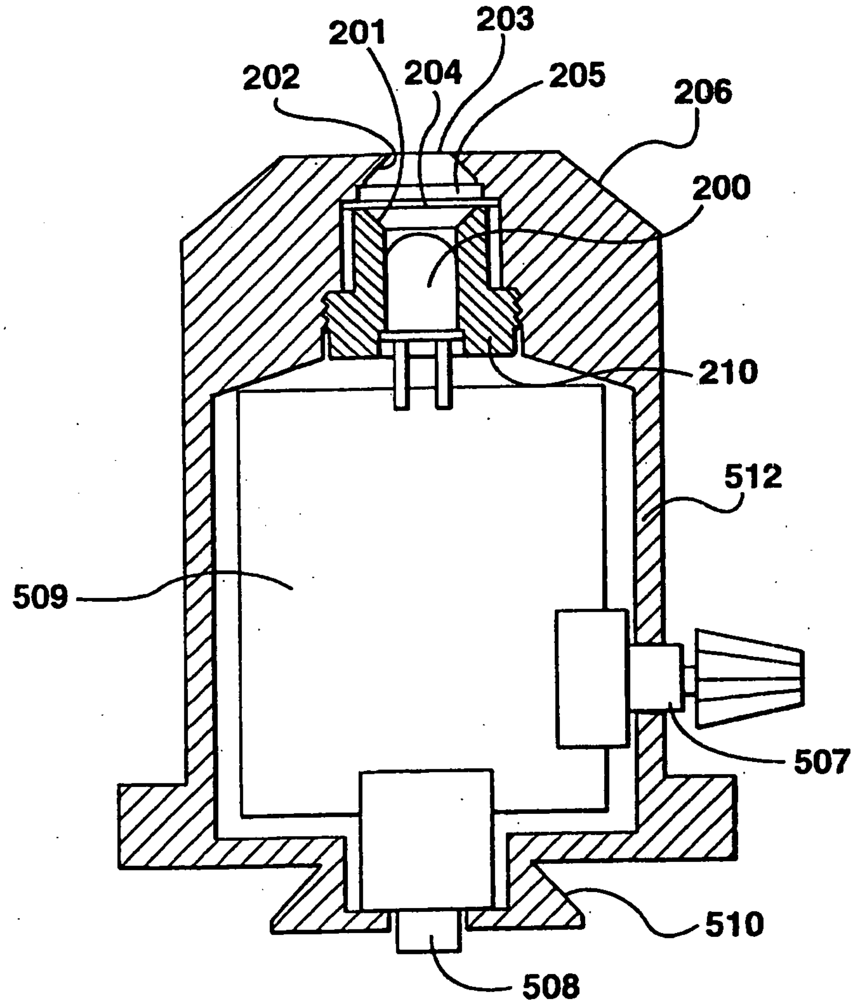


FIG. 1

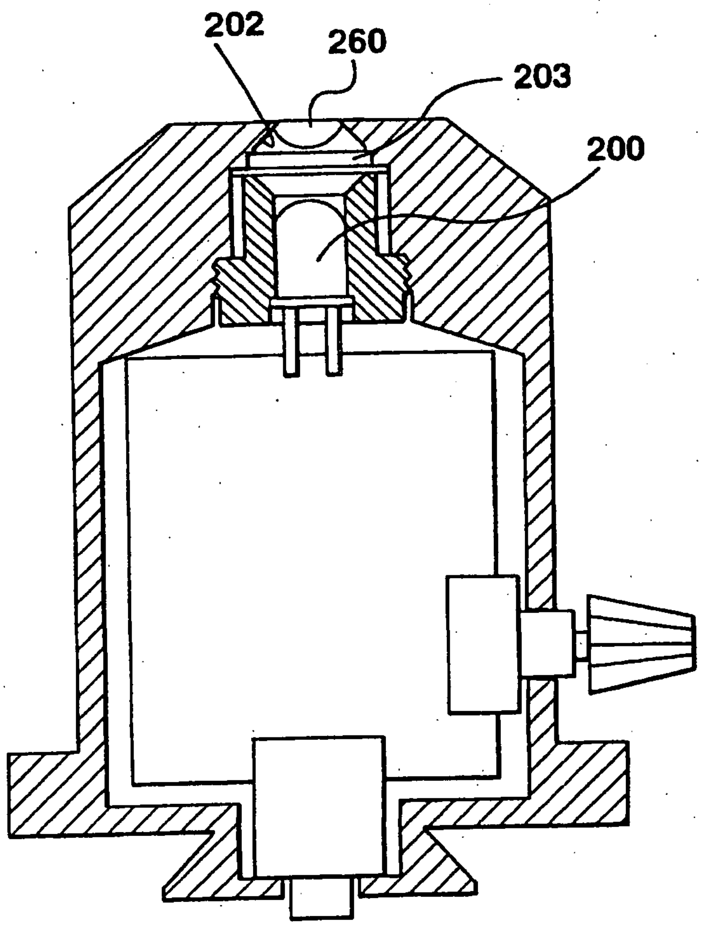


FIG. 2

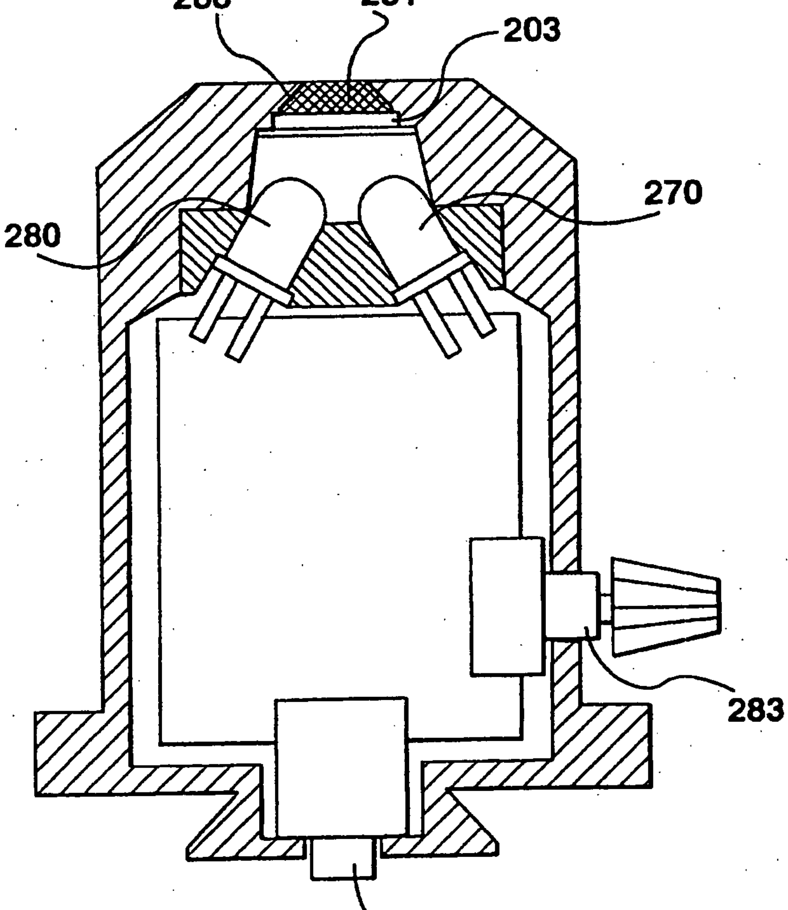


FIG. 3

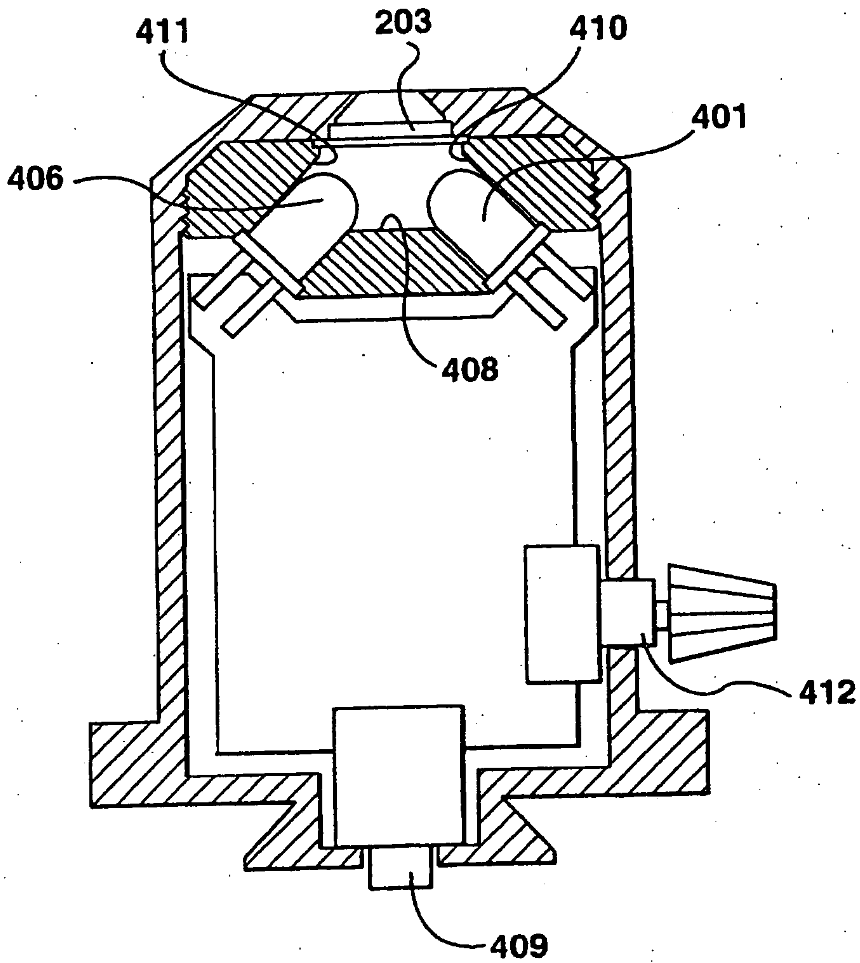


FIG. 4

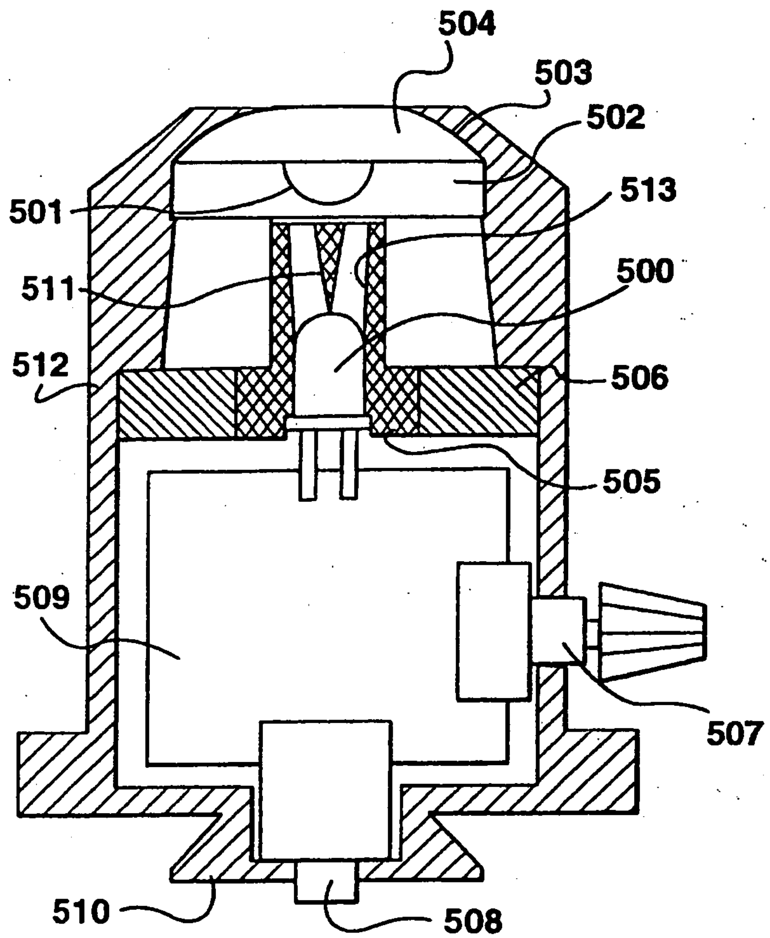


FIG. 5

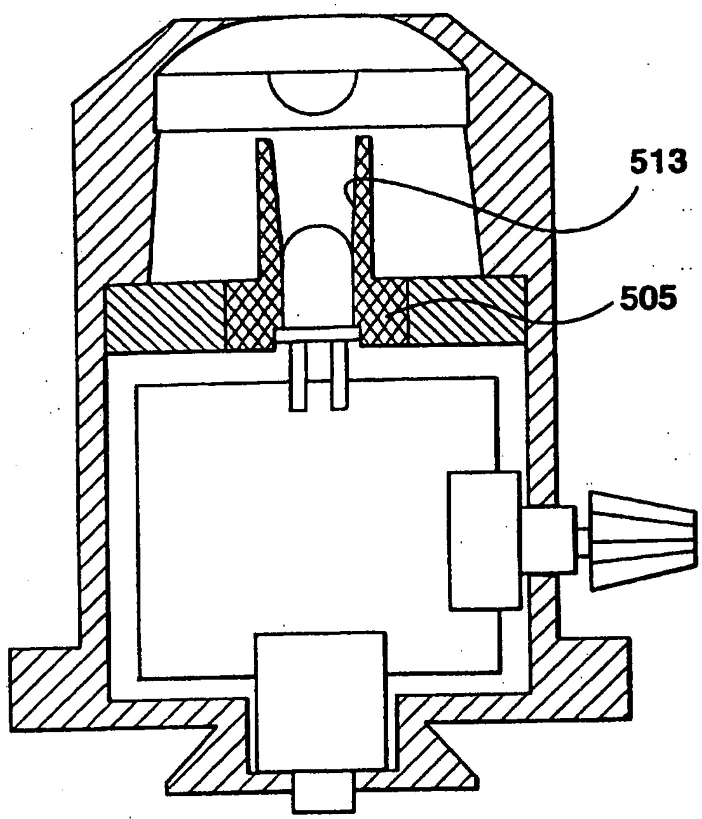


FIG. 6

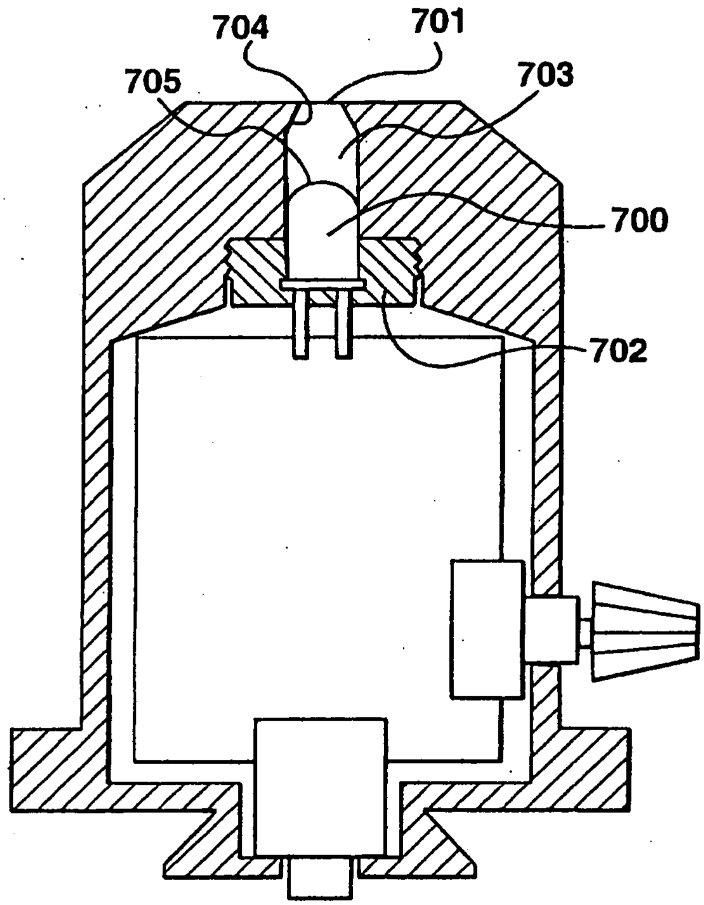


FIG. 7

FIG. 8